

Stokes' Law & Terminal Velocity

Understanding viscous drag and the mechanics of falling spheres in fluids.



Section 9.5.1

» Welcome to Section 9.5.1. Today we are going to understand the exact mechanics of why objects falling through fluids eventually stop accelerating, which is a high-yield topic for competitive exams.

The Raindrop Paradox

- If a raindrop fell under pure gravity, it would hit the ground at lethal speeds.
- In reality, as it falls through a fluid (air), it drags fluid layers with it.
- This relative motion creates an invisible retarding force: **Viscous Drag**.

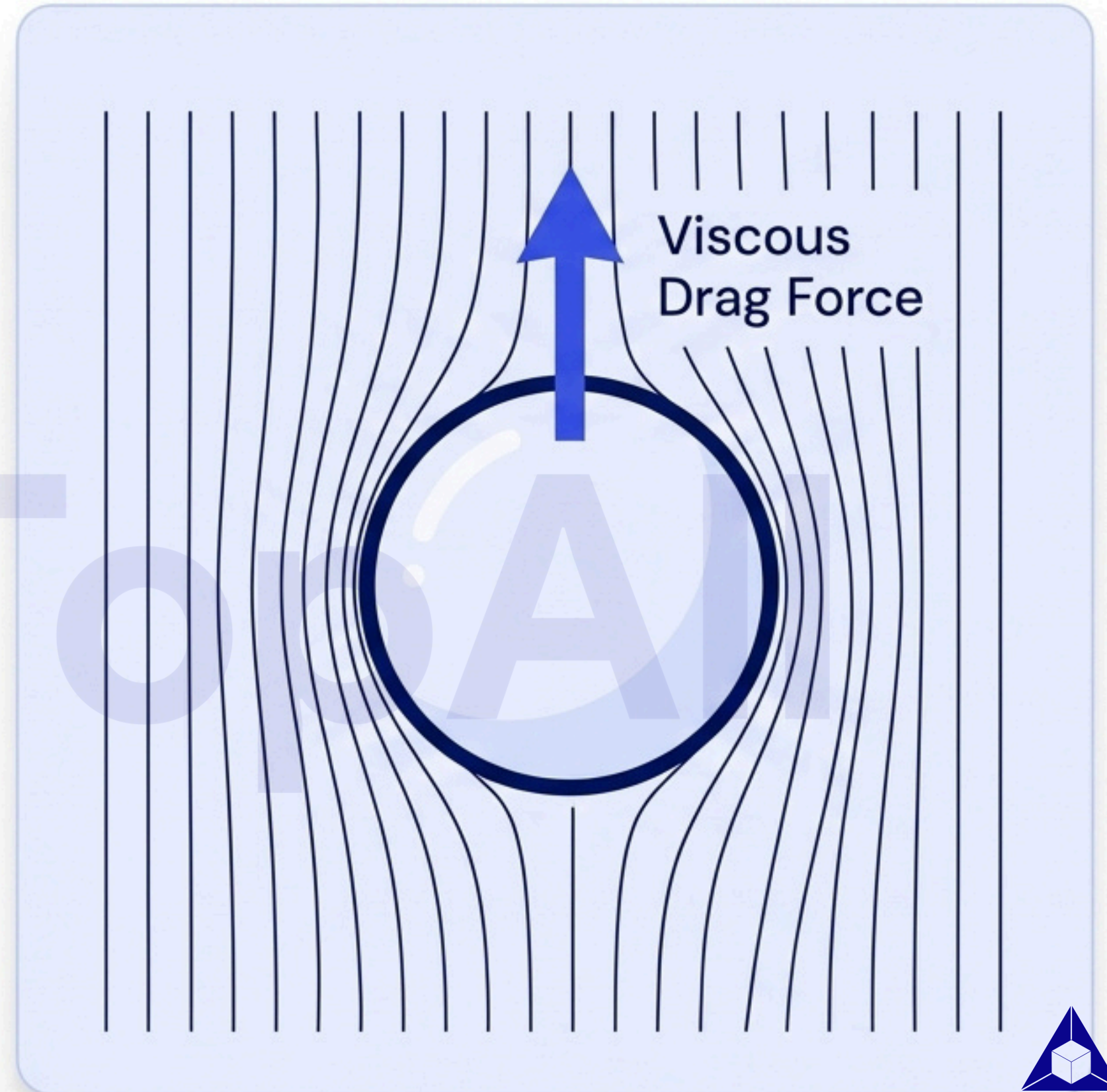


Initially, a sphere accelerates due to gravity. But the faster it goes, the more the fluid pushes back.

[STOKES' LAW]

The Physics of Viscous Drag

- When a body falls through a fluid, it drags the layer of fluid in contact with it.
- This sets up relative motion between different layers of the fluid.
- The fluid exerts a retarding viscous force that directly opposes the sphere's motion.





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The Viscous Drag Formula

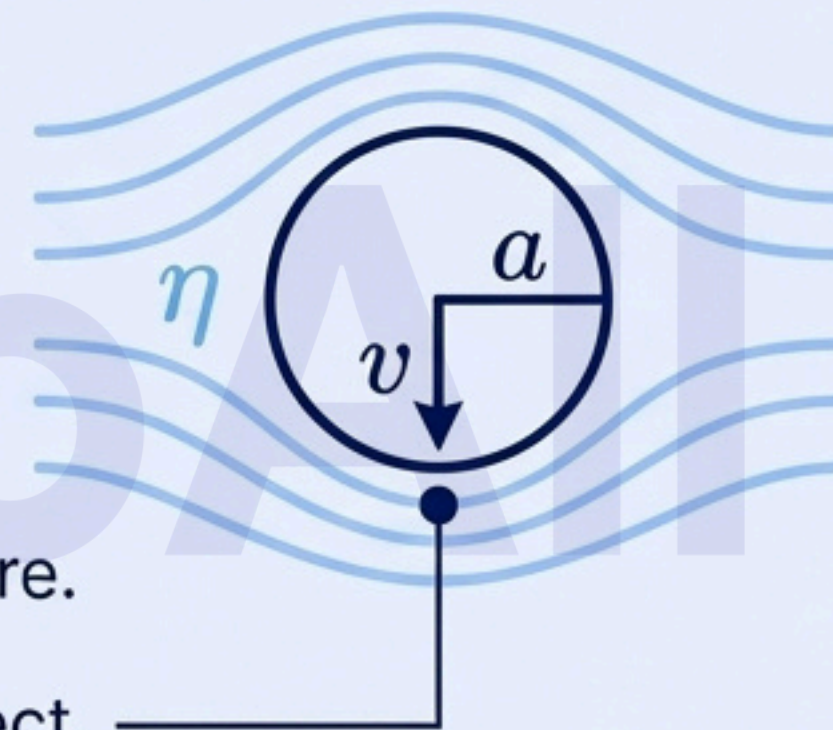
[FORMULA 9.17]

$$F = 6\pi\eta av$$

η (eta): Coefficient of viscosity of the fluid.

a : Radius of the sphere.

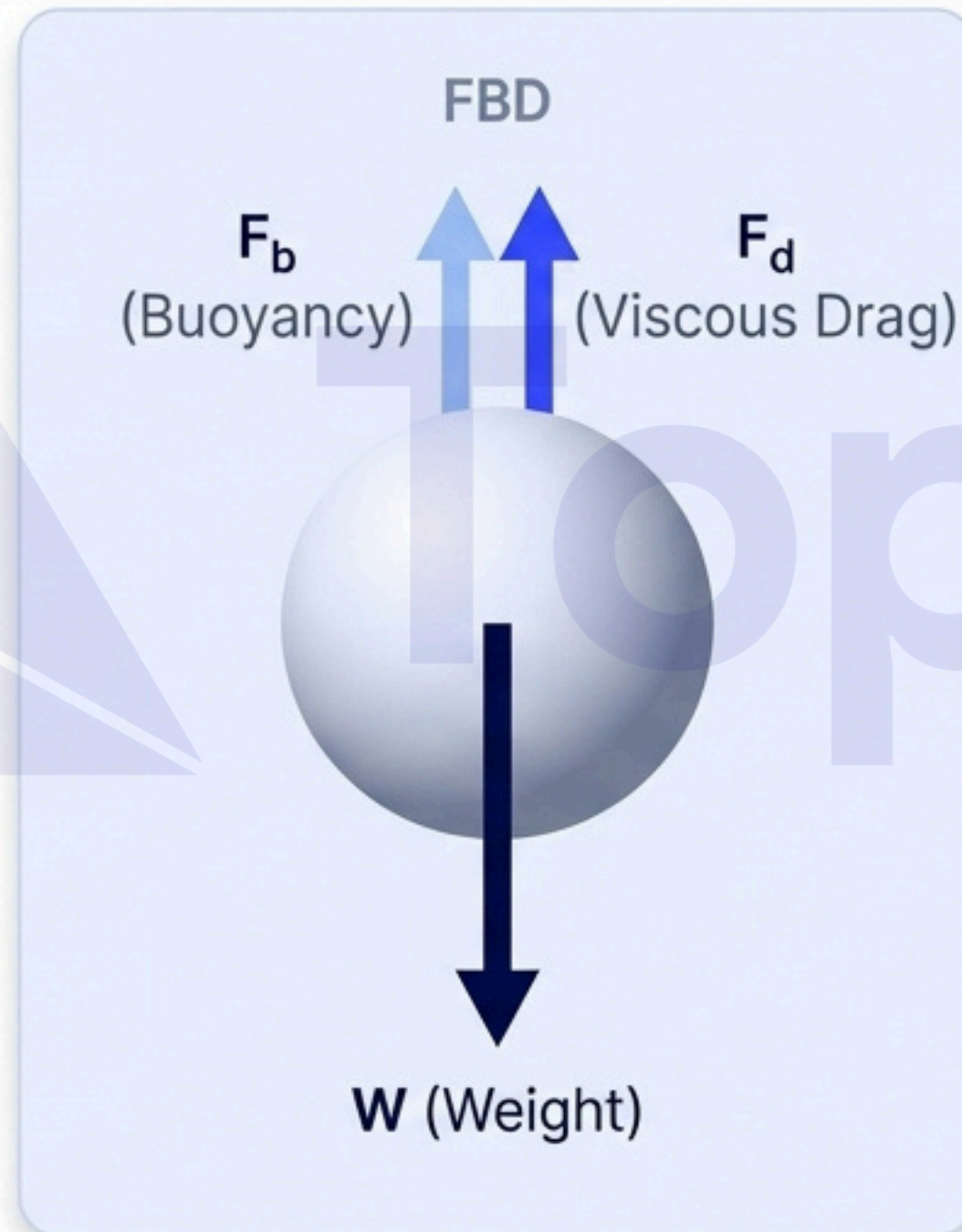
v : Velocity of the object.



[EXAM TIP] Drag force increases linearly as velocity increases!

Achieving Equilibrium

As velocity increases, viscous drag increases. Eventually, net force becomes zero.
The sphere falls with a constant Terminal Velocity (v_t).



Balance Equation

$$W = F_b + F_d$$


Downward:

- Weight ($W = \frac{4}{3} \pi a^3 \rho g$)

Upward:

- Buoyant force ($F_b = \frac{4}{3} \pi a^3 \sigma g$)
- Viscous Drag ($F_d = 6\pi\eta a v_t$)

Deriving the Final Speed

[FORMULA 9.18]

$$v_t = \frac{2a^2(\rho - \sigma)g}{9\eta}$$

Key Dependencies



$$v_t \propto a^2$$

A larger radius yields a much faster terminal velocity (big raindrops fall faster).

$$v_t \propto \frac{1}{\eta}$$

Higher fluid viscosity (e.g., honey vs. air) results in a slower terminal velocity.



$$(\rho - \sigma)$$

Depends on the density difference between the sphere and the fluid.

Master Stokes' Law

- [✓] Viscous drag opposes motion: $F = 6\pi\eta a v$ (Stokes' Law).
- [✓] Equilibrium brings constant speed: Terminal velocity occurs when downward Weight perfectly balances upward Buoyancy and Drag.
- [✓] Size matters most: Terminal velocity scales exponentially with the square of the radius (a^2).

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